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## THE FLIGHT OF THE BLACK-CAPPED CHICKADEE AND THE WHITE-BREASTED NUTHATCH

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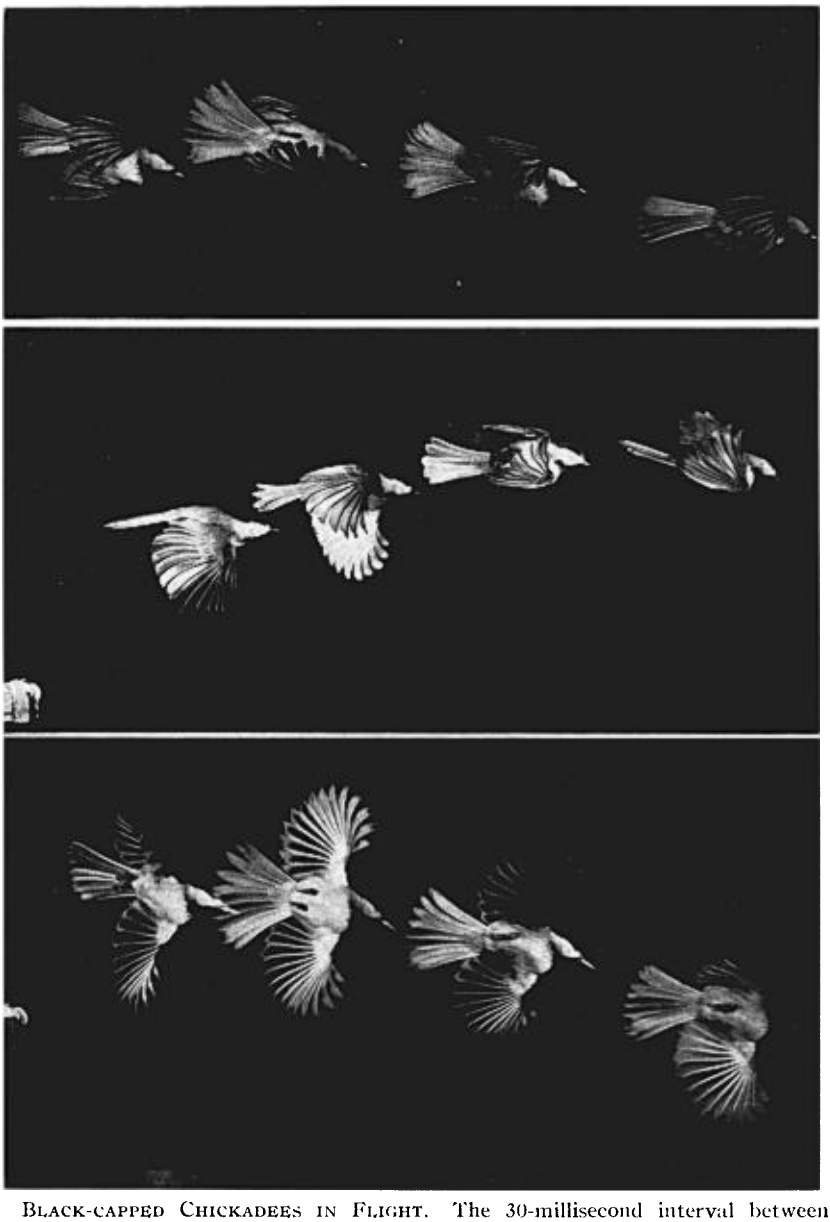
FOR several winters, my wife and I have maintained a feeding station for birds at our home near Wilmington, Delaware. This, quite naturally, has led to photographing the birds which come to the feeding tray. The most constant and fearless visitors are the Black-capped Chickadees (*Parus atricapillus*) and the White-breasted Nuthatches (*Sitta carolinensis*), and for these species I have a large enough series of photographs to permit a study of the acceleration, flight speed, and rate of wing beat.

I will not go into specific detail on the equipment used, for that has very little to do with the conclusions. Let me say simply that I used a four- by five-inch view camera so placed that the object : image-size ratio is about four to one. The illumination was by four Heiland Strobonars. Our electronics experts devised for me a piece of equipment which set off these lights successively at controllable time intervals, these intervals being precise to one per cent. I was thus able to get four successive images of the same bird. The usual time interval between images was 30 milliseconds. The apparatus was set off by the bird passing through a photoelectric beam about four inches from the end of a seven- by two-inch feeding tray. The camera was focussed so that the first image was clearly in the field of view, and after some experimentation, I was able to secure conditions which gave me four images on the same film. A black velvet background was used to remove the influence of the ordinary daylight illumination.

The distance through which a bird moved in the interval between flashes was measured directly on the pictures, and the difference between the distances moved between two successive pairs of pictures was used to calculate acceleration. The data obtained by these methods are presented in tables 1 and 2. In a few instances, owing

WHITE-BREASTED NUTHATCHES LANDING AND TAKING OFF. The interval between successive images is 30 milliseconds.



BLACK-CAPPED CHICKADEES IN FLIGHT. The 30-millisecond interval between images almost exactly coincides with the interval between successive wing beats

TABLE 1

SEQUENCE FLIGHT PICTURES—BLACK-CAPPED CHICKADEE

| *Speed in meters per second* | *Number of measurements* (1) | (2) | (3) | *Acceleration in meters per second* | *Number of measurements* (4) | (5) |
|---|---|---|---|---|---|---|
| 2.3 | 2 | — | — | | | |
| 2.4 | 2 | — | — | 0 | — | 2 |
| 2.5 | 1 | — | — | | | |
| 2.6 | — | — | — | 0.1 | — | 4 |
| 2.7 | 2 | — | — | | | |
| 2.8 | 8 | 1 | — | 0.2 | 3 | 4 |
| 2.9 | 1 | — | — | | | |
| 3.0 | 1 | — | — | 0.3 | — | 5 |
| 3.1 | 6 | — | — | | | |
| 3.2 | 8 | 2 | — | 0.4 | 8 | 8 |
| 3.3 | 13 | 2 | 2 | | | |
| 3.4 | 2 | — | — | 0.5 | 7 | 1 |
| 3.5 | 7 | 5 | 1 | | | |
| 3.6 | 5 | 4 | 1 | 0.6 | 8 | — |
| 3.7 | 6 | 6 | 1 | | | |
| 3.8 | — | — | — | 0.7 | 10 | — |
| 3.9 | 2 | 8 | 2 | | | |
| 4.0 | 3 | 10 | 3 | 0.8 | 17 | — |
| 4.1 | 1 | 9 | 3 | | | |
| 4.2 | — | 4 | 1 | 0.9 | 5 | — |
| 4.3 | — | 6 | 2 | | | |
| 4.4 | 1 | 1 | 2 | 1.0 | 2 | — |
| 4.5 | 1 | 2 | 5 | | | |
| 4.6 | — | — | — | 1.1 | — | — |
| 4.7 | 1 | 1 | — | | | |
| 4.8 | — | 2 | — | 1.2 | 3 | — |
| 4.9 | — | 1 | 1 | | | |
| *Total measurements* | 73 | 64 | 24 | *Total measurements* | 63 | 24 |
| *Average speed in meters per second* | 3.31 | 3.95 | 4.10 | *Average acceleration in meters per second* | 0.68 | 0.26 |
| *Average speed in miles per hour* | 7.25 | 8.65 | 9.00 | *Average acceleration in miles per hour* | 1.49 | 0.57 |
| *Minimum speed mph* | 5.0 | 6.2 | 7.3 | *Minimum acceleration* | 0.44 | 0 |
| *Maximum speed mph* | 10.3 | 10.8 | 10.8 | *Maximum acceleration* | 2.63 | 1.10 |

(1) Number of pictures in which the speed was measured between images 1 and 2.
(2) Number of pictures in which the speed was measured between images 2 and 3.
(3) Number of pictures in which the speed was measured between images 3 and 4.
(4) Number of times the stated increase in speed was measured, increase being the difference between the speeds as observed from images 2 and 3 and images 1 and 2.
(5) Number of times the stated increase in speed was measured, increase being the difference between the speeds as observed from images 3 and 4 and images 2 and 3.

to malfunctioning of the apparatus, I got only two images on a given negative. In most cases, however, I got three, and in about one-third of the pictures, there were four.

As I have indicated above, the feeding tray was seven inches long and the light beam four inches from one end of it. Thus the bird's take-off position could vary substantially. For example, if it took off from the far end of the tray and its head tripped the beam, it would have flown very nearly eleven inches before the first picture

TABLE 2

SEQUENCE FLIGHT PICTURES—WHITE-BREASTED NUTHATCH

| *Speed* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *In meters per second* | *In separation on negative in mm.* | *Number of measurements* (1) | (2) | (3) | *Acceleration Separation in mm.* | *Number of measurements* (4) | (5) |
| 2.4 | 16 | 1 | — | — | 3 | 2 | 8 |
| | 17 | — | — | — | | | |
| 2.7 | 18 | 4 | — | — | 4 | 8 | 5 |
| | 19 | 2 | — | — | | | |
| 3.0 | 20 | 3 | 1 | — | 5 | 6 | 5 |
| | 21 | 3 | 1 | — | | | |
| 3.3 | 22 | 2 | 2 | — | 6 | 4 | — |
| | 23 | 3 | 1 | — | | | |
| 3.6 | 24 | — | 2 | — | | | |
| | 25 | — | 3 | 3 | | | |
| 3.9 | 26 | 1 | 5 | 1 | | | |
| | 27 | 1 | 3 | 1 | | | |
| 4.2 | 28 | — | — | 4 | | | |
| | 29 | — | — | 1 | | | |
| 4.5 | 30 | — | — | 3 | | | |
| | 31 | — | — | 3 | | | |
| 4.8 | 32 | — | 2 | — | | | |
| | 33 | — | — | — | | | |
| 5.1 | 34 | — | — | — | | | |
| | 35 | — | — | 2 | | | |
| *Total measurements* | | 20 | 20 | 18 | *Number* | 20 | 18 |
| *Average speed in meters per second* | | 3.11 | 3.80 | 4.35 | *Average separation* | 4.6 | 3.8 |
| *Average speed in miles per hour* | | 6.8 | 8.3 | 9.5 | *Acceleration in meters per second* | 0.69 | 0.57 |
| *Minimum speed mph* | | 5.2 | 6.6 | 8.2 | *Acceleration in miles per hour* | 1.5 | 1.2 |
| *Maximum speed mph* | | 8.9 | 10.5 | 11.5 | | | |

(1) Number of pictures in which the speed was measured between images 1 and 2.
(2) Number of pictures in which the speed was measured between images 2 and 3.
(3) Number of pictures in which the speed was measured between images 3 and 4.
(4) Number of times the stated increase in speed was measured, increase being the difference between the speeds as observed from images 2 and 3 and images 1 and 2.
(5) Number of times the stated increase in speed was measured, increase being the difference between the speeds as observed from images 3 and 4 and images 2 and 3.

was taken, whereas if it took off from the edge of the tray nearest the beam, it would have flown something less than four inches. This I think explains the rather wide variation (between 5 and 10 mph) in the speed as measured between the first two images. Note, for example, that the speed as measured between images 3 and 4 is much more constant. I conclude from this that the bird approaches terminal velocity quite rapidly, and I would guess that for the chickadee, terminal velocity is somewhere around 11 mph and occurs after four or five wing beats. This is also borne out by measurements of ac-

celeration, in which the rate of increase of the bird's speed decreases quite rapidly between successive images.

With the nuthatch, on the other hand, the initial speed is somewhat less, and the final speed somewhat greater. The acceleration measurements indicate that the nuthatch is still speeding up as it flies out of the picture area. This is perhaps to be expected, since the nuthatch is a substantially bigger bird with larger wings and stronger wing action.

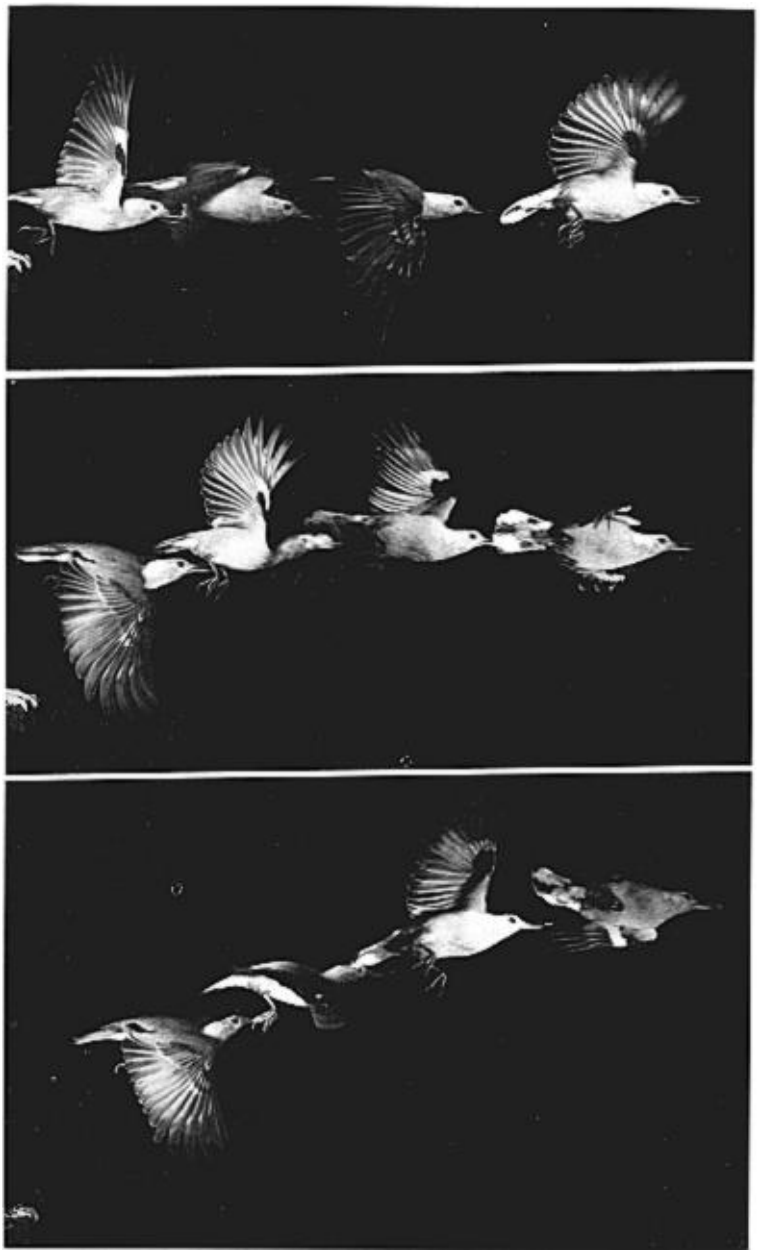
To reduce the variability of the first image with respect to the take-off position, I constructed a much smaller feeding tray. This tray was mounted on a vertical spring so arranged that the bird started the photographic apparatus as it kicked the tray in taking off. The two lower pictures in plate 1 were made in this way. While there are too few pictures taken in this series to justify statistical treatment, those which I have show a rather constant initial speed which is near the lowest speeds calculated from pictures taken with the other apparatus. From these experiments and from some still pictures which I have taken, I would conclude that before taking off, a bird flexes its knees and raises its wings and that minimum flying speed is reached by the bird's hopping and simultaneously giving its wings a strong down-beat. Curiously enough, the take-off speeds of all the small birds which I have photographed are approximately the same, in the order of 5 mph.

The constancy of the wing position in successive pictures of the chickadee is remarkable (plate 2). The chance selection of 30 milliseconds as the interval between pictures coincided with the period between wing beats in this species. We can therefore conclude that the wings of this species beat 33 times per second and that there is in this rate remarkably little variation. I would estimate it to be plus or minus not more than five per cent. At least two different individuals were photographed.

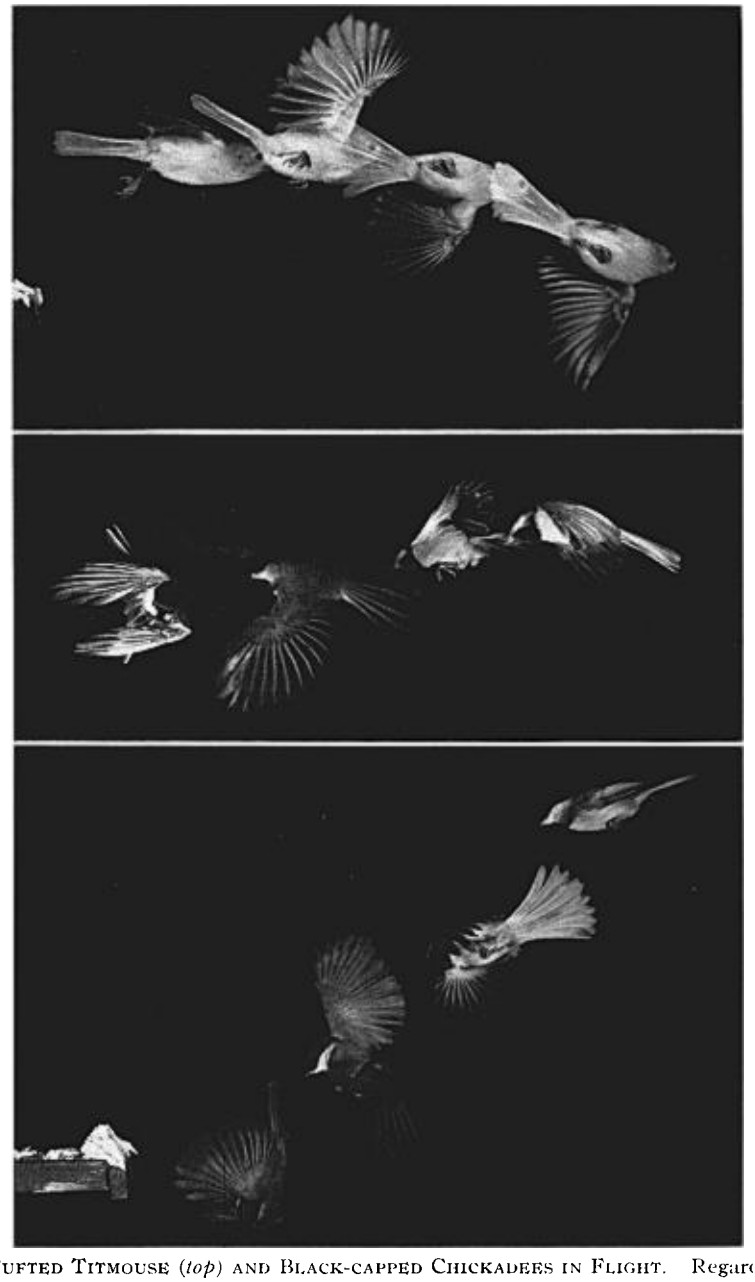
I did not determine the wing beat of the nuthatch with equal precision. This, however, was estimated by the position of the wing in successive pictures, and I arrived at a figure of 25 wing beats per second for this larger bird.

From these data, together with what Harold Edgerton has given me for the hummingbird and from what I have read about larger birds, I wonder if the speed of the wing tip would not turn out to be approximately constant irrespective of bird size. This seems justified, at least on the basis of a rough approximation; and it also seems reasonable from what I know of aerodynamic principles.

In nearly all of the pictures, the head of the bird points in the



WHITE-BREASTED NUTHATCHES IN FLIGHT. In this species, the interval between successive wing beats is greater than the 30-millisecond interval between the images



TUFTED TITMOUSE (*top*) AND BLACK-CAPPED CHICKADEES IN FLIGHT. Regardless of the position of the body, the head points in the direction of flight.

direction in which the bird is flying. This is quite independent of the position of its body; in fact, in some pictures the bird seems almost turned over on its back yet its head is right side up and quite clearly pointing in the direction of flight. The first image on plate 4, upper figure, shows a Tufted Titmouse (*Parus bicolor*) right side up; in the second, its body is turned toward the camera; in the third, it is completely upside down; and in the fourth, it has again turned so that its belly is facing the camera. The bird is banking away from the background, but the degree to which it has overcorrected seems quite unusual.

We also took some pictures in which the bird is coming in to the feeder. Originally, this was done to see how fast the bird's reactions might be (plate 4). This reaction must be extremely rapid, for between the first flash, which presumably frightened the bird, and the second flash, 30 milliseconds later, it had begun to change its course. Perhaps better evidence lies in the fact that when we take single pictures with the photobeam four inches from the edge of the feeding tray, the bird coming in for a landing is frightened and before reaching the tray is able to change his direction of flight rapidly enough to fly away without touching the feeder.

We are continuing to take photographs of this sort, hoping in due time to obtain similar data for our other winter visitors. I am also designing a high-speed moving-picture camera capable of accelerating to full speed in 1/100 second or less, in an effort to study more precisely the remarkable control and speed of reaction of these small birds.

*Greenville, Delaware, August 17, 1953.*

[Other articles on Mr. Greenewalt's work in the field of bird photography have appeared in *Colliers*, December 27, 1952, p. 66, and in *Audubon Magazine*, March–April 1954, p. 58.—EDITOR.]